Advanced Java Programming

After mastering the basics of Java you will now learn more complex but important programming concepts as implemented in Java.

Review: Previous Class

- What you have learned in your prerequisite class: some variables directly contain data:

```
num1 = 12
num2 = 3.5;
ch = 'a';
```

- What you may have learned your perquisite class: some variables ‘refer’ to other variables.

```
list = []
list = [1,2,3]
```

James Tam

Review: This Class

- In Java when you use objects and arrays there are two things involved:
  - Reference
  - Object (or array)
- Example with an object

```
Person charlie;   // Creates reference to object
charlie = new Person("Sheen");   // Creates object
```

- Example with an array

```
double [] salaries; // Creates reference to array
salaries = new double[100];   // Creates array
```

James Tam

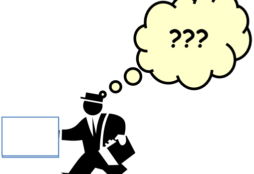
Addresses And References

- Real life metaphor: to determine the location that you need to reach the 'address' must be stored (electronic, paper, human memory)

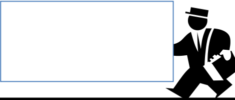
121

122

123



- Think of the delivery address as something that is a 'reference' to the location that you wish to reach.
  - Lose the reference (electronic, paper, memory) and you can't 'access' (go to) the desired location.



James Tam

Adressesses And References

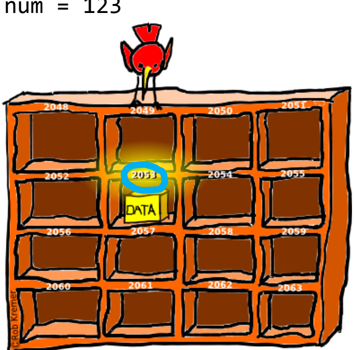
- A reference to an array does not directly contain the contents of a string
  - Instead the reference contains the address (“refers to”) of the array

James Tam

Recap: Variables

- Variables are a ‘slot’ in memory that contains ‘one piece’ of information.

```
num = 123
```



- Normally a location is accessed via the name of the variable.
  - Note however that each location is also numbered!

Image: Curtesy of Rob Kremer

James Tam

References And Objects

- Full example under:
  "/home/219/examples/advanced/1shallowDeep/0referenceExamples"

```
public class Person
{
    private String name;
    public Person() {  name = "none";  }

    public Person(String newName) {  setName(newName);
    }

    public String getName() {  return(name);  }

    public void setName(String newName) {
        name = newName;
    }
}
```

James Tam

References And Objects (2)

- In `main()`:

```
Person bart;
Person lisa;

bart = new Person("bart");
System.out.println("Bart object name: " + bart.getName());

lisa = bart;
bart = new Person("lisa");
System.out.println("Bart object name: " + bart.getName());
System.out.println("Lisa object name: " + lisa.getName());
```

```
Bart object name: bart
```

```
Bart object name: lisa
```

```
Lisa object name: bart
```

James Tam

References And Objects (3)

- What happened?

```
Person bart;
Person lisa;
bart = new Person("bart");
lisa = bart;
bart = new Person("lisa");
```

bart `@ = 200` → Address = 200 (Person object) "lisa"

lisa `@ = 100` → Address = 100 (Person object) "bart"

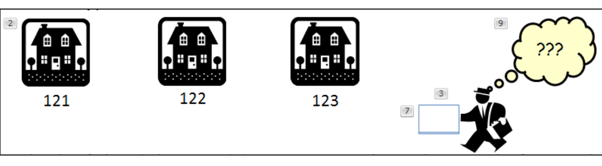
James Tam

References And Objects (4)

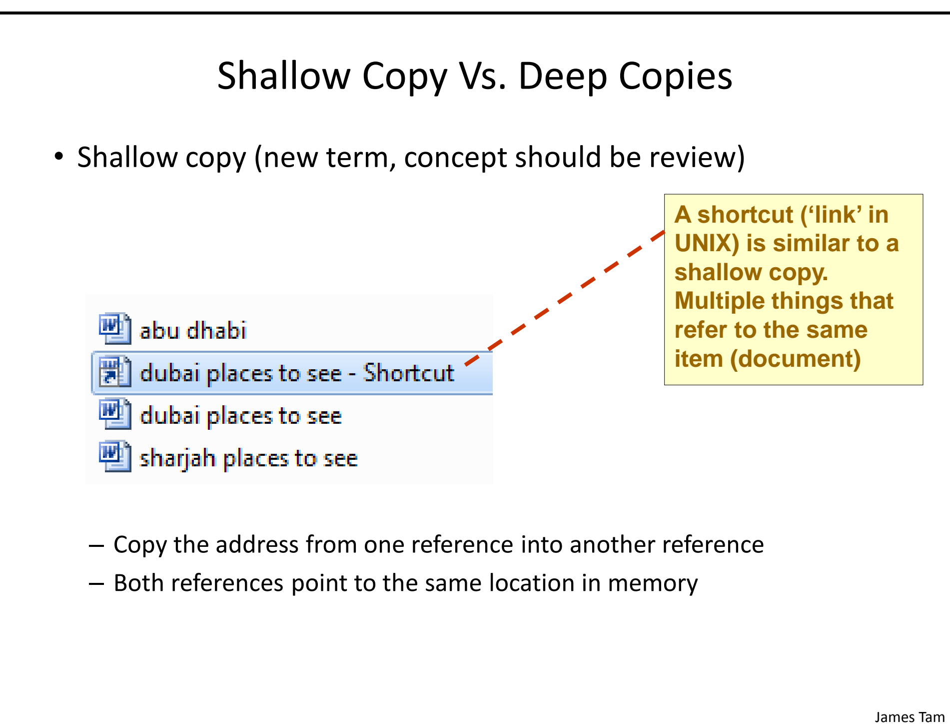
```
Person bart;
Person lisa;
bart = new Person("bart");
lisa = bart;
bart = new Person("lisa");
```

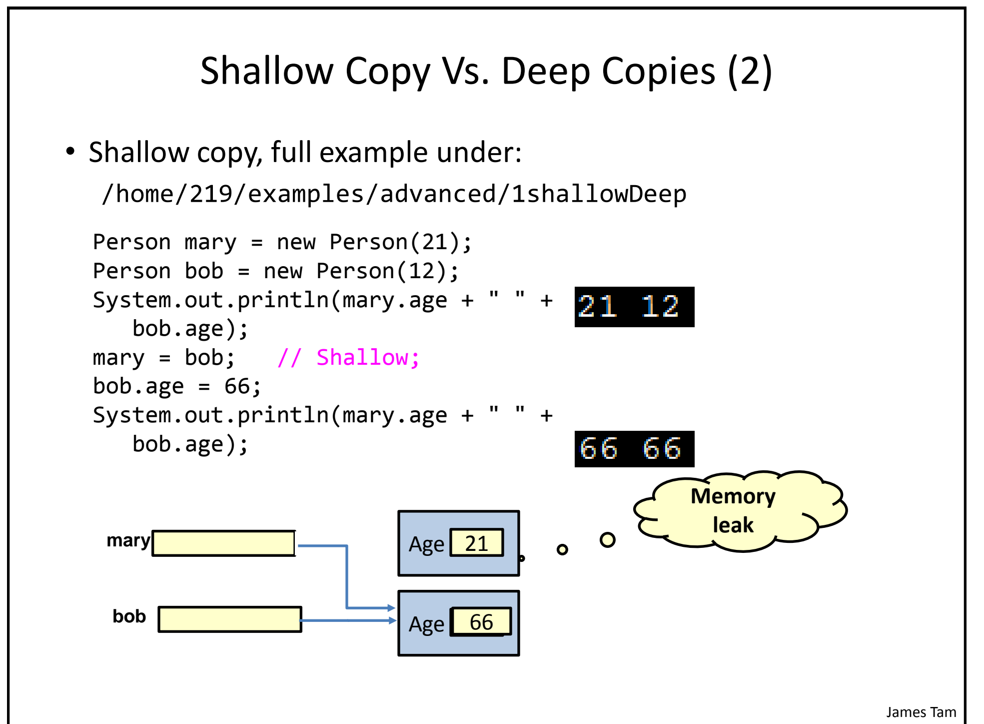
Note:

- The object and the reference to the object are separate e.g., 'bart' originally referenced the 'bart object' later it referenced the 'lisa object'
- The only way to access the object is through the reference.
- These same points applies for all references (arrays included)



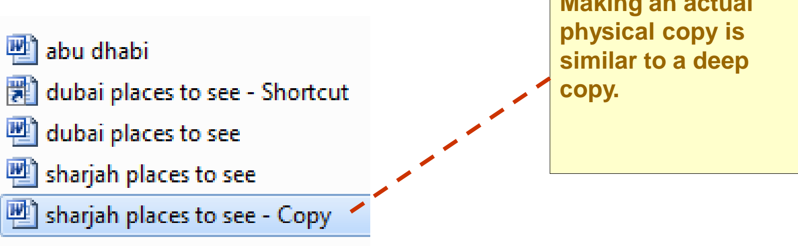
James Tam


Shallow Copy Vs. Deep Copies
• Shallow copy (new term, concept should be review)
A shortcut ('link' in UNIX) is similar to a shallow copy. Multiple things that refer to the same item (document)
abu dhabi
dubai places to see - Shortcut
dubai places to see
sharjah places to see
– Copy the address from one reference into another reference
– Both references point to the same location in memory
James Tam


Shallow Copy Vs. Deep Copies (2)
• Shallow copy, full example under:
/home/219/examples/advanced/1shallowDeep
Person mary = new Person(21);
Person bob = new Person(12);
System.out.println(mary.age + " " +
bob.age);
mary = bob; // Shallow;
bob.age = 66;
System.out.println(mary.age + " " +
bob.age);
21 12
66 66
Memory leak
mary
bob
Age 21
Age 66
James Tam

Shallow Copy Vs. Deep Copies (3)

- Deep copy (new term, concept should be review)



- Don't copy addresses stored in the references
- Instead the data referred to by the references are copied
- After the copy each reference still refers to a different address (data variable)

James Tam

Shallow Copy Vs. Deep Copies (4)

- Deep copy, full example under:
  `/home/219/examples/advanced/1shallowDeep`

```
// Mary still 66
bob = new Person(77);
mary.age = bob.age;     // Deep
bob.age = 144;
System.out.println(mary.age + " " +
   bob.age);
```

```
77 144
```

mary → Age 77

bob → Age 144

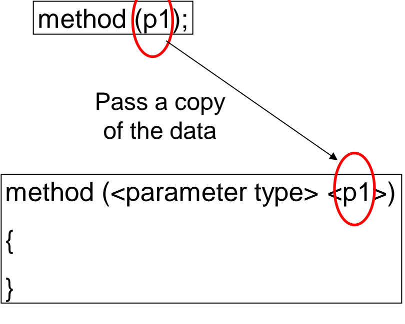
James Tam

Methods Of Parameter Passing

- Pass by value
  - The data stored (the "*value*" stored) in the parameter is copied
- Pass by reference
  - Pass the address of the parameter
  - This allows references to the parameter inside the method (the method has a "*reference*" to the original parameter).

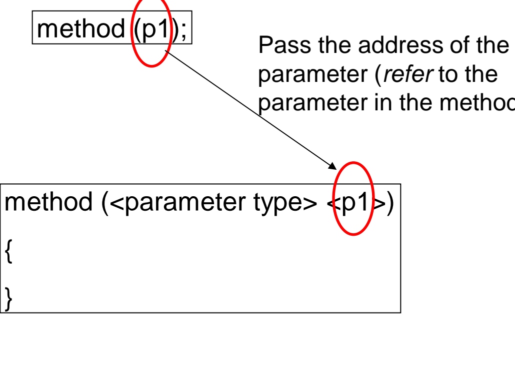
James Tam

Passing Parameters As Value Parameters



James Tam

Passing Parameters As Reference Parameters



James Tam

Which Parameter Passing Mechanism Is Used?

Passed by value

- All 'simple' built in types:
  - Integers (`byte`, `short`, `int`, `long`)
  - Floating point (`float`, `double`)
  - Character (`char`)
  - Boolean (`boolean`)

Pass by reference

- Objects
- Arrays
- (That is anything that consists of a reference and the item referenced).

Parameter Passing Example

- Full example under:
  `/home/219/examples/advanced/2parameters`

James Tam

Class Person

```
public class Person {
    private int age;
    private String name;

    public Person() {
        age = -1;
        name = "none";
    }

    public int getAge() {
        return(age);
    }

    public String getName() {
        return(name);
    }
```

James Tam

Class Person (2)

```
    public void setAge(int anAge) {
        age = anAge;
    }

    public void setName(String aName) {
        name = aName;
    }
}
```

James Tam

Class ParameterExample

```
public class ParameterExample
{
    public void modify(Person aPerson, int aNum)
    {
        aPerson.setName("Eric Cartman");
        aPerson.setAge(10);
        aNum = 888;
        System.out.println("Person inside modify()");
        System.out.println(aPerson.getName() + " " +
                           aPerson.getAge());
        System.out.println("Number inside modify()");
        System.out.println(aNum);

    }
}
```

Modifies parameters here

James Tam

The Driver Class

```
public class Driver
{
    public static void main(String [] args)
    {
        int num = 13;
        Person aPerson = new Person();
        ParameterExample pe = new ParameterExample();

        System.out.println("Person in main() before edit");
        System.out.println(aPerson.getName() + " " +
                           aPerson.getAge());
        System.out.println("Number inside main() before edit");
        System.out.println(num);
        System.out.println("----------");
```

```
Person in main() before edit
none -1
Number inside main() before edit
13
```

The Driver Class (2)

```
        pe.modify(aPerson,num);
        System.out.println("----------");
```

```
public void modify(Person aPerson, int aNum)
{
    aPerson.setName("Eric Cartman");
    aPerson.setAge(10);
    aNum = 888;
```

```
Person inside modify()
Eric Cartman 10
Number inside modify()
888
```

```
        System.out.println("Person in main() after edit");
        System.out.println(aPerson.getName() + " " +
                           aPerson.getAge());
        System.out.println("Number inside main() after edit");
        System.out.println(num);

    }
}
```

```
Person in main() after edit
Eric Cartman 10
Number inside main() after edit
13
```

Previous Example: Analysis

- Why did the parameter that was passed by reference change and the simple type (passed by value) did not?

James Tam

Benefits Of Employing References

- References require a bit more complexity but provide several benefits over directly working with objects and arrays.
- Benefit 1: As you have just seen a reference contains the address of ‘something’ (object, array).
  - As long as the address of the object or array is retained changes made inside the method will persist.
  - Recall that functions or methods can only return zero or one things (passing out of a function after it ends).
  - Passing by reference (passing into the function just as it starts executing) allows more than one change to persist after the function has ended:

```
fun (refernce1, reference2, reference3…etc.)
```

James Tam

Benefits Of Employing References (2)

- Benefit 2: If an array or object is large then it may be much more memory efficient to pass a reference instead.
- Example:
  - References are typically 32 or 64 bits in size.
  - An array or object will almost always be larger.

```
char [] array1 = new char[1000000]; // 2 MB

class SocialNetworkUser
{
    // attribute for images
    // attribute for videos

}
```

James Tam

Modifying Simple Types (Parameters)

- Only one thing to be changed: return the updated value after the method ends)
- More than one thing to be changed:
  - Pass an array (e.g., three integers must be modified in a method then pass an array of integers with 3 elements).
  - Employ a wrapper (class).

Image copyright unknown

James Tam

Wrapper Class

- A class definition built around a simple type

e.g.,

```
public class IntegerWrapper
{
     private int num;
     public int getNum () { return num; }
     public void setNum (int newNum) { num = newNum; }
}
```

- Also Wrapper classes are also used to provide class-like capabilities (i.e., methods) to simple variable types e.g., class `Integer`
  - http://docs.oracle.com/javase/6/docs/api/java/lang/Integer.html
  - Example useful method `parseInt(String)`: converting strings to integers

```
int num = Integer.parseInt("123");  // More on this later
```

James Tam

Arrays: Parameters And Return Values

- Full example under:

`/home/219/examples/advanced/3arrayParameters`

- **Format, method call**:
  - When the method is called, passing an array as a parameter and storing a return value appears no different as other types.
  - Example (`list1` and `list2` are arrays)

```
list2 = ape.oneDimensional(list1);
```

James Tam

Arrays: Parameters And Return Values (2)

- **Format, method definition**:
  - Use 'square brackets' to indicate that the return value or parameter is an array.
  - Each dimension requires an additional square bracket.
  - One dimensional:

```
public int [] oneDimensional(int [] array1)
```

  - Two dimensional:

```
public char [][] twoDimensional(char [][] array1)
```

James Tam

Array Of 'Objects'

- Although referred to as an array of objects they are actually arrays of references to objects.
- Recall for arrays 2 steps are involved to create array

```
int [] array;           // Reference to array
array = new int[3];     // Creates array of integers
```

- Recall for objects 2 steps are also required to create object

```
Person jim;           // Reference to Person object
jim = new Person();   // Creates object
```

James Tam

Array Of 'Objects' (2)

- An array of objects is actually an array of references to objects.
- So 3 steps are usually required
  - Two steps are still needed to create the array

```
// Step 1: create reference to array
Person [] somePeople;

// Step 2: create array
somePeople = new Person[3];
```

- In Java after these two steps each array element be null.

```
somePeople[0].setAge(10);  // Null pointer exception
```

  - The third step requires traversal through array elements (as needed): create a new object and have the array element refer to that object.
    - (The third step can typically be skipped for array elements that are supposed to be 'empty')

James Tam

Array Of 'Objects' (3)

- (Step 3: creating objects continued)

```
for (i = 0; i < 3; i++)
{
    // Create object, array element refers to that object
    somePeople[i] = new Person();

    // Now that array element refers to an object, a method
    // can be called.
    somePeople[i].setAge(i);
}
```

James Tam

Array Of Objects: Example

- Location of the full example:
  - /home/219/examples/advanced/4arrayReferences/simple

James Tam

Class Person

```
public class Person
{
    private int age;

    public Person() {
        age = 0;
    }

    public int getAge() {
        return(age);
    }

    public void setAge(int anAge) {
        age = anAge;
    }
}
```

James Tam

Driver Class

```
public class Driver
{
    public static void main(String [] args) {
        Person [] somePeople; // Reference to array
        int i;
        somePeople = new Person[3];  // Create array

        for (i = 0; i < 3; i++) {
            // Create object, each element refers to a newly
            // created object
            somePeople[i] = new Person();

            somePeople[i].setAge(i);
            System.out.println("Age: " +
                                    somePeople[i].getAge());
        }
    }
```

James Tam

Design Example

- Suppose we wanted to simulate a 2D universe in the form of a numbered grid ('World')

```
class World
{
    private [][] Tardis grid;
}
```

- Each cell in the grid was either an empty void or contained the object that traveled the grid ('Tardis')[1]

```
class Tardis
{

}
```

1 Tardis and "Doctor Who" © BBC

James Tam

General Description Of Program

- The 'world/universe' is largely empty.
- Only one cell contains the Tardis.
- The Tardis can randomly move from cell to cell in the grid.
- Each movement of Tardis uses up one unit of energy

James Tam

Designing The World

Class World
- Attributes?
- Methods?

Class Tardis
- Attributes?
- Methods?

CAUTION: STOP READING AHEAD

- JT's note: Normally you are supposed to read ahead so you are prepared for class.
- In this case you will get more out of the design exercise if you don't read ahead and see the answer beforehand.
- That will force you to actually think about the problem yourself (and hopefully get a better feel for some design issues).
- So for now skip reading the slides that follow this one up to the one that has a corresponding 'go' symbol all over it.
- After we have completed the design exercise in class you should go back and look through those slides (and the source code).

Image copyright unknown

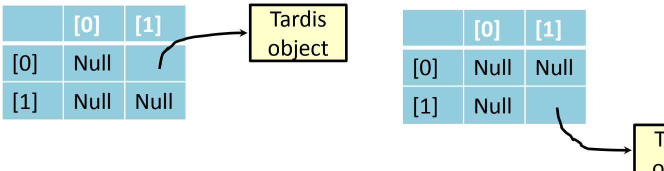
Tardis

- Attributes
  - Current energy level
- Methods:
  - Randomly generating movement:
    - Some method must reduce the energy level as the Tardis moves
    - The actual 'movement' from square to square in the grid will be a responsibility of class `World` because the grid is an attribute of the world.

James Tam

World

- Attributes
  - A 2D array that stores information about the 'universe'
  - Most array elements will be empty (`null`)
  - One element will refer to the Tardis object
  - The maximum number of rows and columns
  - The current location (row/column) of the Tardis
    - Needed to 'move' the Tardis from source cell to destination cell



  - Theoretically the (row/col) could be (int, int) but because at most one item can be returned from a method the location will be tracked as 1D integer array (details in code):
    - `World.move()->Tardis.calculateCoordinates()`

James Tam

World (2)

- Methods
  - Constructor(s) to create the world
  - Methods that modify the world (e.g., making sure each array element is truly null: `wipe()`
  - Displaying the world: `display()`
  - Changing the contents of the objects in the world (e.g., editing the world or moving objects): `move()`

James Tam

Manager

- It is responsible for things like determining how long the simulation runs.
- For very simple programs it may be a part of the `World` class (in this case it's part of the `Driver`).
- But more complex programs (e.g., need to track many pieces of information like multiple players, current scores etc. and simulation rules) may require a separate `Manager` class.
  - The `Driver` will then likely be responsible for instantiating a `Manager` object and calling some method of the manager to start the simulation.

James Tam

END SECTION: Proceed Reading

- You can continue reading ahead to the slides that follow this one.
  - JT: Thank you for your understanding and co-operation.

Source Code: Design Exercise

- Location of the full source code:
  `/home/219/examples/advanced/4arrayReferences/doctor`

James Tam

Class Tardis

```
public class Tardis
{
    private int energy;

    public Tardis(int startEnergy) {
        energy = startEnergy;
    }
    // max row and column define the size of the world
    public int[] calculateCoordinates(int maxRow, int maxColumn) {
        Random aGenerator = new Random();
        int [] newCoordinates = new int[2];
        newCoordinates[0] = aGenerator.nextInt(maxRow);
        newCoordinates[1] = aGenerator.nextInt(maxColumn);
        energy--;
        return(newCoordinates);
    }
}
```


e.g., = 4 **e.g., = 7**

0, 1, 2, 3

0, 1, 2, 3, 4, 5, 6

James Tam

Class World: Attributes

```
public class World
{
    private Tardis [][] grid;  // Simulated world
    private int maxRow;     // Row capacity
    private int maxColumn;  // Column capacity
    private int [] currentLocation;  // (row/col) of Tardis
```

James Tam

Class World: Constructor

```
    public World() {
        // Element 0: current row the tardis is located
        // Element 1: current column the tardis is located
        currentLocation = new int[2];

        Scanner in = new Scanner(System.in);
        System.out.print("Max rows: ");
        maxRow = in.nextInt();
        System.out.print("Max columns: ");
        maxColumn = in.nextInt();
        grid = new Tardis[maxRow][maxColumn];
        wipe();   // Empties the world, sets everything to null
        grid[0][0] = new Tardis(10); // Tardis starts top left
        currentLocation[0] = 0;  // Tardis row = 0
        currentLocation[1] = 0;  // Tardis col = 0
        display();
    }
```

James Tam

Class World: Initialization

```
public void wipe()
{
    int r;
    int c;
    for (r = 0; r < maxRow; r++)
    {
        for (c = 0; c < maxColumn; c++)
        {
            grid[r][c] = null;
        }
    }
}
```

e.g., max = 2 (maxRow)

e.g., max = 3 (maxColumn)

r = 0, c = {0,1,2}

r = 1, c = {0,1,2}

	[0]	[1]	[2]
[0]	null	null	null
[1]	null	null	null

James Tam

Class World: Display

```
public void display()
{
    int r;
    int c;
    for (r = 0; r < maxRow; r++)
    {
        for (c = 0; c < maxColumn; c++)
        {
            if (grid[r][c] == null)
                System.out.print(".");
            else
                System.out.print("T");
        }
        System.out.println();
    }
}
```

e.g., = 4 (maxRow)

e.g., = 7 (maxColumn)

Move cursor to display new row on next line (System.out.println();)

	0	1	2	3	4	5	6
0	T	.	.	.	.	.	
1	.	.	.	.	.	.	
2	.	.	.	.	.	.	
3	.	.	.	.	.	.	

James Tam

Movement

- To make it look like the Tardis has 'moved'.
- Set the destination (row/column) to refer to the Tardis object.
- Set the source (row/column) to null

Before move

	[0]	[1]
[0]	Null	
[1]	Null	Null

Tardis object

After move

	[0]	[1]
[0]	Null	Null
[1]	Null	

Tardis object

James Tam

Class World: Move

```
public void move()
{
    // currentLocation 1D array stores Tardis location
    int currentRow = currentLocation[0];
    int currentColumn = currentLocation[1];

    // Keep track of where the Tardis is currently located
    int oldRow = currentRow;
    int oldColumn = currentColumn;

    // Store new (row/col) in 1D array (currentLocation)
    currentLocation =
        grid[currentRow][currentColumn].calculateCoordinates
            (maxRow,maxColumn);
```

Recall:
`Tardis.currentCoordinates()`
randomly generates a new (row/column) location

James Tam

Class World: Move (2)

```
// Update temporary values with current location
currentRow = currentLocation[0];
currentColumn = currentLocation[1];

// Copy tardis from the old location to the new one.
grid[currentRow][currentColumn] = grid[oldRow][oldColumn];

// Check if tardis trying to move onto same square, don't
// 'wipe' if this is the case or tardis will be lost
// (Tardis object becomes a memory leak).
if ((currentRow == oldRow) &&
    (currentColumn == oldColumn)) {
      System.out.println("Same location");
}
else {
      // 'wipe' tardis off old location
      grid[oldRow][oldColumn] = null;
}
```

James Tam

Class World: Move (3)

```
    System.out.println("Tardis re-materializing");
    display();
}
```

James Tam

The `Driver` Class (Also The "Manager")

```
public class Driver
{
    public static void main(String [] args)
    {
        Scanner in = new Scanner(System.in);
        World aWorld = new World();
        int i;
        for (i = 0; i < 10; i++)
        {
            aWorld.move();
            System.out.println("Hit enter to continue");
            in.nextLine();
        }
        System.out.println("\n<<<Tardis is out of energy,
           end simulation>>> \n");
    }
}
```

James Tam

Universally Accessible Constants

- What you currently know
  - How to declare constants that are local to a method

```
class Driver {
    main() {
        final int A_CONST = 10;
    }
}
```

- If you need constants that are accessible throughout your program then declare them as class constants.

James Tam

Declaring Class Constants

- **Format:**

```
public class <class name>
{
    public final static <type> <NAME> = <value>;
}
```

- **Example:**

```
public class Person
{
    public final static int MAX_AGE = 144;
}
```

- Note: Because constants cannot change it is okay to set the access level to public.

James Tam

Accessing Class Constants

- **Format** (outside of the class definition)[1]:

```
<class name>.<constant name>;
```

- **Example** (outside of the class definition):

```
main()
{
    System.out.println("Max life span: " + Person.MAX_AGE);
}
```

- Accessing a constant inside the methods of that class do not require the name of the class

```
public class Person {
    …
    public void fun() { System.out.println(MAX_AGE); }
}
```

James Tam

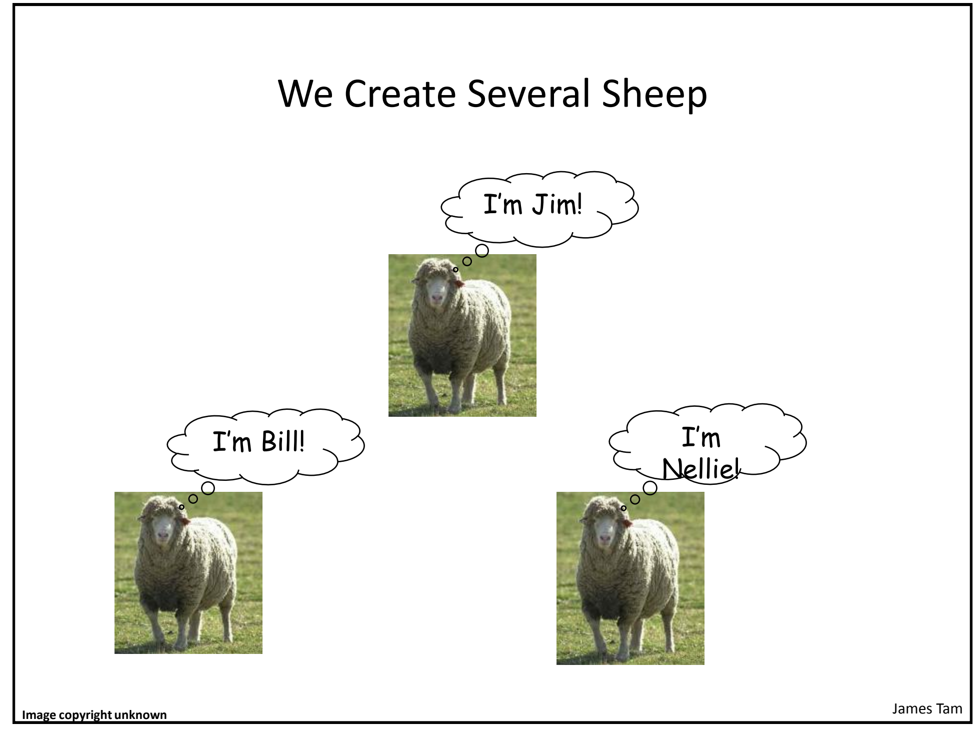
Introducing A New Concept With..Class Sheep!

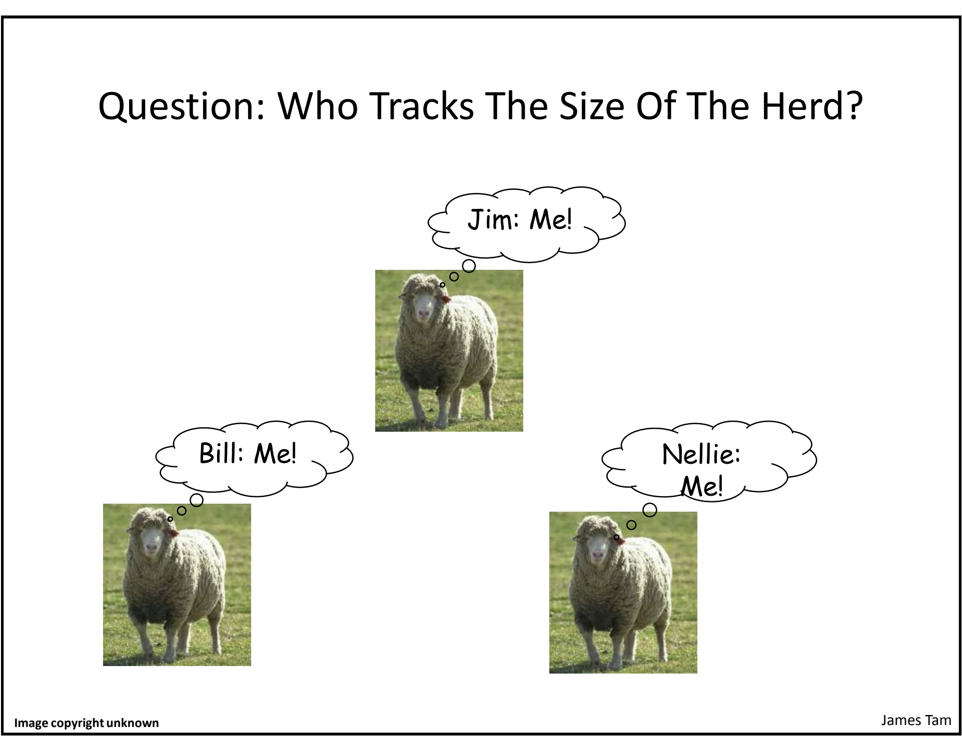
```
public class Sheep
{
    private String name;

    public Sheep()
    {
        name = "No name";
    }
    public Sheep(String aName)
    {
        setName(aName);
    }
    public String getName() { return name;}

    public void setName(String newName) { name = newName; }
}
```

James Tam





Answer: None Of The Above!

- Information about all instances of a class should not be tracked by an individual object.
- So far we have used instance fields.
- Each *instance* of an object contains *it's own set of instance fields* which can contain information unique to the instance.

```
public class Sheep
{
     private String name;
       . . .
}
```

Object	Object	Object
name: Bill	name: Jim	name: Nellie

James Tam

The Need For Static (Class Attributes)

- Static fields: One instance of the attribute exists *for the class* (not one attribute for each instance of the class)

Class Sheep
flockSize

Object
name: Bill

Object
name: Jim

Object
name: Nellie

James Tam

Static (Class) Methods

- Are associated with the class as a whole and not individual instances of the class.
  - Can be called without having an instances (because it's called through the class name not a reference/instance name).
  - Instance method:

```
Scanner in = new Scanner(System.in);
in.nextInt();    // refName.method()
```

  - Class Method:

```
double squareRoot = Math.sqrt(9);   // ClassName.method()
```

- Typically implemented for classes that are never instantiated e.g., class `Math`.

James Tam

Accessing Static Methods/Attributes

- Inside the class definition

Format:

```
– <attribute or method name>
```

Example:

```
public Sheep ()
  {
      flockSize++;
  }
```

James Tam

Accessing Static Methods/Attributes (2)

- Outside the class definition

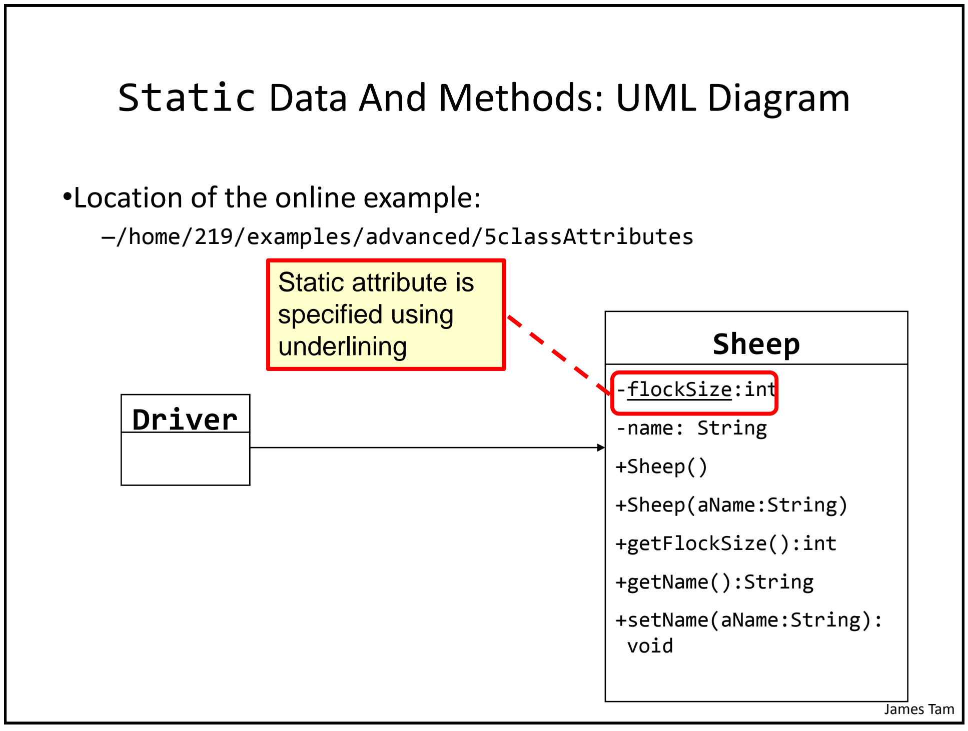
Format:

```
<Class name>.<attribute or method name>
```

Example:

```
Sheep.getFlockSize();
```

James Tam



Static Data And Methods: The Driver Class

```
public class Driver
{
    public static void main(String [] args) {
        System.out.println();
        System.out.println("You start out with " +
                            Sheep.getFlockSize() +
                           " sheep");
        System.out.println("Creating flock...");
        Sheep nellie = new Sheep("Nellie");
        Sheep bill = new Sheep("Bill");
        Sheep jim = new Sheep();
        System.out.println("Current count " +
                            Sheep.getFlockSize());
    }
}
```

James Tam

Static Data And Methods: The Sheep Class

```
public class Sheep
{
    private static int flockSize = 0;
    private String name;

    public Sheep() {
        flockSize++;
        name = "No name";
    }
    public Sheep(String aName) {
        flockSize++;
        setName(aName);
    }

    public static int getFlockSize () { return flockSize; }
    public String getName() { return name;}
    public void setName(String newName) { name = newName; }
}
```

James Tam

Rules Of Thumb: Instance Vs. Class Fields

- If a attribute can differ between instances of a class:
  - The field probably should be an instance field (non-static)
- If the attribute field relates to the class (rather to a particular instance) or to all instances of the class
  - The field probably should be a static field of the class

James Tam

Rule Of Thumb: Instance Vs. Class Methods

- If a method can be invoked regardless of the number of instances that exist (e.g.., the method can be run when there are no instances) then it probably should be a static method.
- If it never makes sense to instantiate an instance of a class then the method should probably be a static method.
  - E.g., the class doesn't have any variable attributes only static constants such as class `Math`
- Otherwise the method should likely be an instance method.

James Tam

Static Vs. Final

- **Static**: Means there's one instance of the attribute for the class (not individual instances for each instance (object) of the class)
- **Final**: Means that the attribute cannot change (it is a constant)

```
public class Foo
{
    public static final int num1= 1;
    private static int num2;  /*  Rare */
    public final int num3 = 1;  /* Why bother (waste) */
    private int num4;
     :           :
}
```

James Tam

An Example Class With A Static Implementation

```
public class Math
{
  // Public constants
  public static final double E = 2.71…
  public static final double PI = 3.14…

  // Public methods
  public static int abs (int a);
  public static long abs (long a);
            :         :
}
```

- For more information about this class go to:
  - http://docs.oracle.com/javase/7/docs/api/java/lang/Math.html

James Tam

Should A Class Be Entirely Static?

- Generally it should be avoided if possible because it often bypasses many of the benefits of the Object-Oriented approach.
- Usually purely static classes (cannot be instantiated) have only methods and no data (maybe some constants).
- Example (purely for illustration):

```
Math math1 = new Math();
Math math2 = new Math();
// What's the difference? Why bother?
math1.abs() vs. math2.abs();
```

- When in doubt *DO NOT* make attributes and methods static.

James Tam

What You Should Know: Attributes Vs. Locals

- Attributes: Defined inside a class definition but outside the body of a method.

```
class Person {
    private int age;
}
```

- Locals: Defined inside the body of a method.

```
class Person {
    public void Person(){
        Scanner in = new Scanner(System.in);
    }
}
```

James Tam

Reminder: Scope

- Attributes
  - Declared within the body of a class but outside a method
  - Accessible anywhere with the class methods

```
class Person {
    private int age;
    public Person() { age = 12; }
    ...
}
```

Scope of attributes and methods

- Local variables
  - Declared inside the body of a method and only accessible in that method

```
class Person {
    public Person () {
        Scanner in = new Scanner(System.in);
    }
}
```

Scope of locals

James Tam

Self Reference: The 'This' Reference

- From every (non-static) method of an object there exists a reference to the object (called the "this" reference) [1]

```
main(String args []) {
  Person fred = new Person();
  Person barney = new Person();
  fred.setAge(35);
}

public class Person {
     private int age;
     public void setAge(int anAge) {
         age = anAge;
    }
            …
 }
```

This is one reason why methods must be invoked via a reference name (the contents of the reference 'fred' will be copied into the 'this' reference (so both point to the 'Fred' object).

The 'this' reference is implicitly passed as a parameter to all non-static methods. One use of 'this' is to distinguish which object's method is being invoked (in this case Fred vs. Barney)

1 Similar to the 'self' keyword of Python except that 'this' is a syntactically enforced name.

James Tam

The 'This' Reference Is Automatically Referenced Inside (Non-Static) Methods

```
public class Person {
    private int age;
    public void setAge(int anAge) {
        // These two statements are equivalent
        age = anAge;
        this.age = anAge;
    }
}
```

James Tam

New Terminology

- Explicit parameter(s): explicitly passed (you can see them when the method is called and defined).

```
fred.setAge(10);     // 10 explicit
barney.setAge(num);   // num explicit

public void setAge(int age) { ... }    // age explicit
```

- Implicit parameter: implicitly passed into a method (automatically passed and cannot be explicitly passed): the 'this' reference.

```
public void setAge(int age) { ... }    // 'this' is implicit
```

James Tam

Benefits Of 'This': Attributes

- Another side benefit is the this reference can make it very clear which attributes are being accessed/modified.

```
public class Person
{
    private int age;

    public void setAge(int age) {
        this.age = age;
    }
}
```

Parameter (local variable) 'age'

Attribute 'age'

James Tam

Benefits Of ‘This’: Parameters

- Another side benefit is the `this` reference can make it clear which object is being accessed e.g., when a class method takes as a explicit parameter an instance of that class[1]

```
main (String [] args) {
    Person fred = new Person();
    Person barney = new Person();
    barney.nameBestBuddy(fred);    // JT: Explicit? Implicit?
}
// JT: What will be the output?
public void nameBestBuddy(Person aPerson) {
    println(this.name + “ best friend is “ + aPerson.name);
}
```

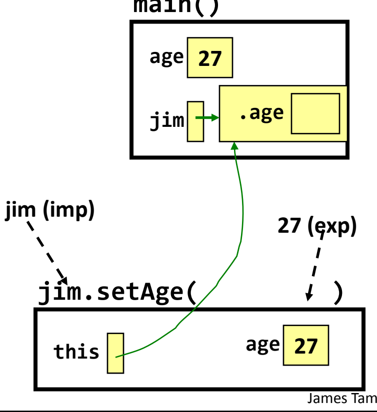
1 JT: more on this one later – see the ‘`equals()`’ method

James Tam

Benefits Of ‘This’: Scope

- Recall: according to scoping rules, local variables are not accessible outside of that function or method (unless returned back to the caller or passed into another method).

```
main (String [] args) {
    int age = 27;
    Person jim = new Person();
    jim.setAge(age);
}
class Person {
    public void setAge(int age) {
        this.age = age;
}
```



Normally the object referred to by the ‘`jim`’ reference not accessible outside of `main()` but the ‘`this`’ reference contains it’s address (implicit pass by reference)

James Tam

Static Methods: No 'This' Reference

- Recall: **static methods** do not require an object to be instantiated because they are invoked via the **class name** not a reference name.

```
int result = Math.abs(-12);
```

- That means static methods do not have the implicit 'this' parameter passed in.
- Also recall I said for now avoid [for the 'Driver' class]:
  - Defining attributes for the Driver
  - Defining methods for the Driver (other than the main method)

James Tam

Static Methods: No 'This' Reference (2)

```
public class Driver
{
    private int num;
    public static void main(String [] args)
    {
        num = 123;
    }
}
```

Driver.java:6: error: non-static variable num cannot be referenced from a static context

- Main() must be static! Automatically called when the program runs via 'java Driver' before any other code.
- If main() were non-static it would require an object to be instantiated (which must occur inside of a method).
- But there would be no way to call that method that instantiates an object without a starting static method.
- Because main() must be static, it has no 'this' implicit parameter which in turn means that non-static attributes like 'num' cannot be accessed (although static attributes/methods accessible): Driver.static_name or just via static_name

James Tam

Mutable Vs. Immutable Types

- Mutable types
  - Original memory can be modified

```
int num = 666;
num = 777;
```

- Immutable types
  - The original memory location cannot be modified
  - Assigning new values will create a new memory location and leave the original untouched.

```
String s1 = “abc”;
String s2 = s1;
s1 = “xyz”;
System.out.println(s1 + “ “ + s2);
```

James Tam

Mutable Vs. Immutable

- Advantage of mutable types: speed
- Advantage of immutable types: ‘security’

James Tam

Mutable Advantage: Speed

- Location of full examples:
  - /home/219/examples/advanced/6mutableImmutable/speed

```
public class StringExample {
   public static void main
     (String [] args) {
        String s = "0";
        int i;
        for (i = 1; i < 100000; i++)
            s = s + i;
    }
}
```

```
public class StringBufferExample {
  public static void main
    (String [] args) {
        StringBuffer s;
        int i;
        s = new StringBuffer("0");
        for (i = 1; i < 100000; i++)
            s = s.append(i);
     }
}
```

James Tam

Immutable Advantage: Security

- Location of the full example:
  - /home/219/examples/advanced/6mutableImmutable/security

James Tam

Class SecurityExample

```
public class SecurityExample
{
    private String s;
    private StringBuffer sb;

    public SecurityExample() {
        s = new String("Original s");
        sb = new StringBuffer("Original sb");
    }

    public String getS() {
        return s;
    }

    public StringBuffer getSB() {
        return sb;
    }
}
```

James Tam

The Driver Class

```
public class Driver
{
    public static void main(String [] args)
    {
        SecurityExample se = new SecurityExample();
        String s;
        StringBuffer sb;

        System.out.println("Originals");
        System.out.println("\t" + se.getS());
        System.out.println("\t" + se.getSB());

        s = se.getS();
        sb = se.getSB();
```

```
Originals
        Original s
        Original sb
```

James Tam

The Driver Class (2)

```
        sb.delete(0,sb.length());
        sb.append("lolz! mucked ur data :P");
        s = "lolz! mucked ur data :P";
        System.out.println();

        System.out.println("After modfications");
        System.out.println("Values of locals");
        System.out.println("\t\tString=" + s);
        System.out.println("\t\tStringBuffer=" + sb);


        System.out.println("\tValues of attributes");
        System.out.println("\t\tString=" + se.getS());
        System.out.println("\t\tStringBuffer=" + se.getSB());
    }
}
```

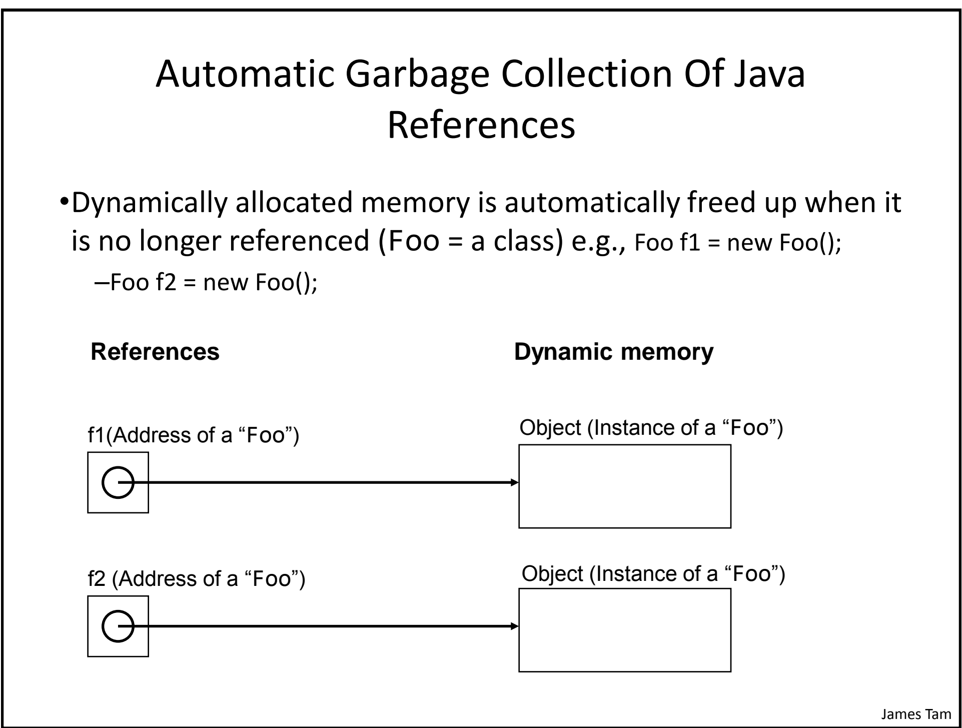
```
Values of locals
        String=lolz! mucked ur data :P
        StringBuffer=lolz! mucked ur data :P
```

```
Values of attributes
        String=Original s
        StringBuffer=lolz! mucked ur data :P
```

James Tam

Automatic Garbage Collection Of Java References

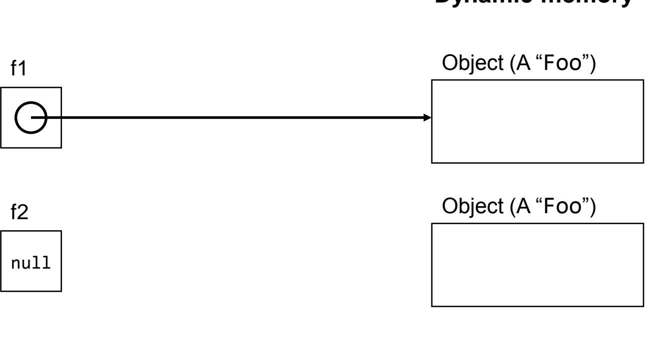
- Dynamically allocated memory is automatically freed up when it is no longer referenced (Foo = a class) e.g., Foo f1 = new Foo();
  - Foo f2 = new Foo();



James Tam

Automatic Garbage Collection Of Java References (2)

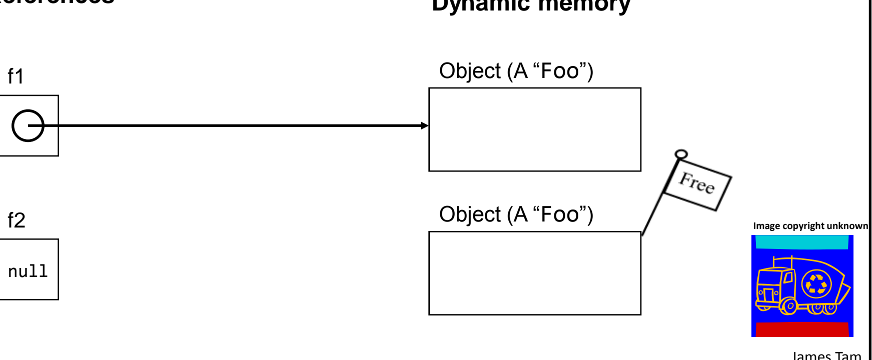
- Dynamically allocated memory is automatically freed up when it is no longer referenced e.g., `f2 = null;`



James Tam

Automatic Garbage Collection Of Java References (3)

- Dynamically allocated memory is automatically freed up when it is no longer referenced e.g., `f2 = null;` (recall that a `null` reference means that the reference refers to nothing, it doesn't contain an address).



James Tam

Caution: Not All Languages Provide Automatic Garbage Collection!

- Some languages do not provide automatic garbage collection (e.g., C, C++, Pascal).
- In this case dynamically allocated memory must be manually freed up by the programmer.
- Memory leak: memory that has been dynamically allocated (such as via the Java 'new' keyword') but has not been freed up after it's no longer needed.
  - Memory leaks are a sign of poor programming style and can result in significant slowdowns.

James Tam

The `Finalize()` Method

- The Java interpreter tracks what memory has been dynamically allocated via 'new'
- It also tracks when memory is no longer referenced.
- When the system isn't busy, the Automatic Garbage Collector is invoked.
- If an object has a finalize method implemented then it is invoked:
  - The finalize is a method written by the programmer to free up non-memory resources e.g., closing and deleting temporary files created by the program, closing network connections.
  - This method takes no arguments and returns no values (i.e., returns void)
  - Dynamic memory is **NOT** freed up by this method.
- After the finalize method finishes execution, the dynamic memory is freed up by the Automatic Garbage Collector.

James Tam

The `Finalize()` Method

- Example sequence:

```
public class Foo
{
      int num;
      public Foo() { num = 1; }
      public Foo(int aValue) { num = aValue; }
      ...
}
      ...
Foo f1 = new Foo ();
```

f1

num 1

The `Finalize()` Method

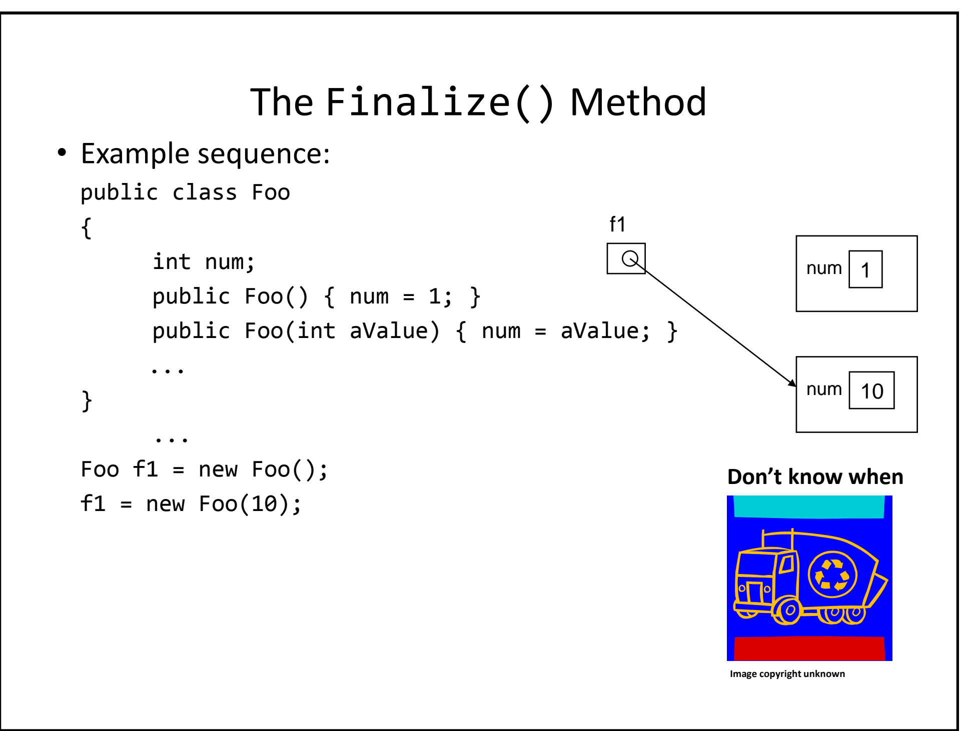
- Example sequence:

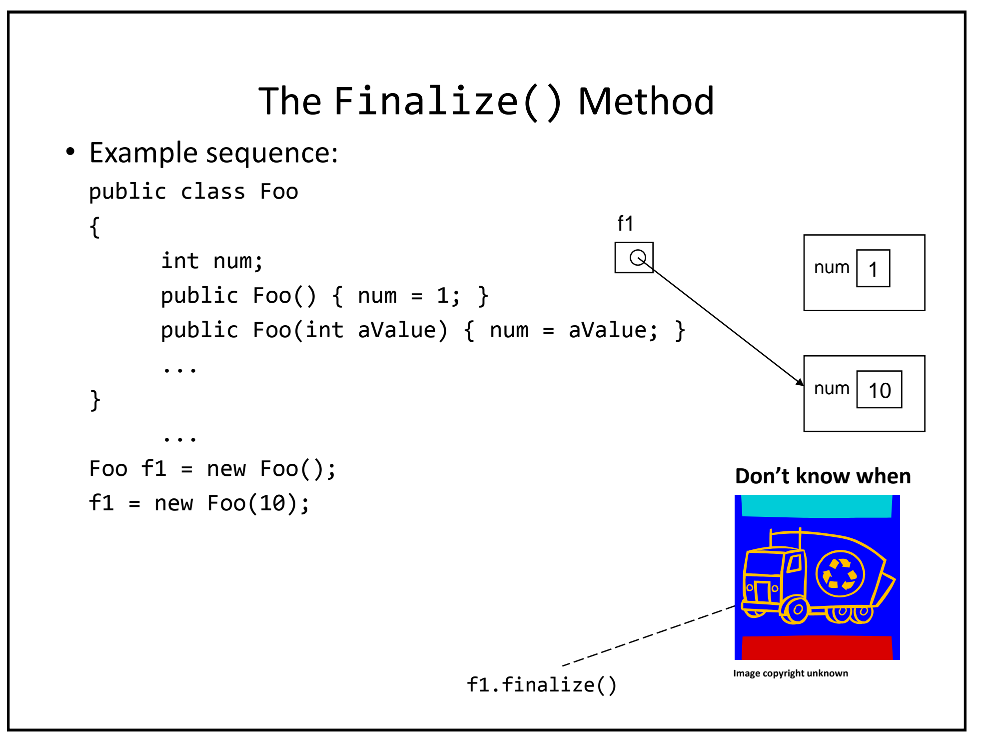
```
public class Foo
{
      int num;
      public Foo() { num = 1; }
      public Foo(int aValue) { num = aValue; }
      ...
}
      ...
Foo f1 = new Foo();
f1 = new Foo(10);
```

f1

num 1

num 10


The Finalize() Method
• Example sequence:
public class Foo
{
int num;
public Foo() { num = 1; }
public Foo(int aValue) { num = aValue; }
...
}
...
Foo f1 = new Foo();
f1 = new Foo(10);
f1
num 1
num 10
Don't know when
Image copyright unknown


The Finalize() Method
• Example sequence:
public class Foo
{
int num;
public Foo() { num = 1; }
public Foo(int aValue) { num = aValue; }
...
}
...
Foo f1 = new Foo();
f1 = new Foo(10);
f1
num 1
num 10
Don't know when
f1.finalize()
Image copyright unknown

The Finalize() Method

- Example sequence:

```
public class Foo
{
      int num;
      public Foo() { num = 1; }
      public Foo(int aValue) { num = aValue; }
      ...
}
      ...
Foo f1 = new Foo();
f1 = new Foo(10);
```

f1

num 1

num 10

Don't know when

Image copyright unknown

f1.finalize()

Example Application Of finalize()

- As a sheep object gets de-allocated from memory (memory is freed up because the object is no longer referenced) the `finalize()` method could update the sheep count.

```
public class Sheep
{
    private int flockSize = 0;
    public Sheep() {
        flockSize++;
    }
    …
    public void finalize() {
        flockSize--;
    }
}
```

Displaying The Current State Of Objects

- The `toString()` method is commonly implemented to allow determination of the state of a particular object (contents of important attributes).
- This method returns a string representation of the state of an object.
- It will automatically be called whenever a reference to an object is passed as a parameter is passed to the "`print()/println()`" method.

`toString()` Example

- Location of the full example:
  - `/home/219/examples/advanced/7toString`

Class Person

```
public class Person
{
    private int height;
    private int weight;
    private String name;

    public Person(String name, int height, int weight)
    {
        this.name = name;
        this.height = height;
        this.weight = weight;
    }
```

Class Person (2)

```
    public String getName()
    {
        return(name);
    }

    public int getHeight()
    {
        return(height);
    }

    public int getWeight()
    {
        return(weight);
    }
```

Class Person (3)

```
    public String toString()
    {
        String s;
        s = "Name: " + name + "\t";
        s = s + "Height: " + height + "\t";
        s = s + "Weight: " + weight + "\t";
        return(s);
    }
}
```

The Driver Class

```
public class Driver
{
    public static void main(String [] args)
    {
        Person jim = new Person("Jim",69,160);
        System.out.println("Atrributes via accessors()");
        System.out.println("\t" + jim.getName() + " " +
                            jim.getHeight() +
                           " " + jim.getWeight());
```

```
Atrributes via accessors()
        Jim 69 160
```

```
        System.out.println("Atrributes via toString()");
        System.out.println(jim);

    }
}
```

```
Atrributes via toString()
Name: Jim       Height: 69      Weight: 160
```

Comparing Objects

- Recall from the discussion of parameter passing (pass by reference) that a reference contains the address of an object or array.
- Using the comparison operator on the references '==' will only determine if the address (and not data) is the same.

```
String s1 = "hi";
String s2 = "hi";


if (s1 == s2)
```

s1 → String object "hi"

s2 → String object "hi"

Comparing Objects (2)

- Either each attribute of each object must be manually compared or else some form of `equals()` method must be implemented.
- Class String has two methods:
  - `compareTo()` # ABC not same as Abc
  - `compareToIgnoreCase()` # ABC same as abc

Implementing Equals()

- Location of the full example:
  - /home/219/examples/advanced/8equals

Class Person

```
public class Person {
    private int height;
    private int weight;

    public Person(int height, int weight) {
        this.height = height;
        this.weight = weight;
    }

    public int getHeight() {
        return(height);
    }

    public int getWeight() {
        return(weight);
    }
```

Class Person (2)

Implicit: Jim   Explicit: Bob

```
    public void setHeight(int height) {
        this.height = height;
    }


    public void setWeight(int weight) {
        this.weight = weight;
    }

    public boolean equals(Person compareTo) {
        boolean flag = true;
        if (this.height != compareTo.getHeight() ||
            this.weight != compareTo.getWeight())
            flag = false;
        return(flag);
    }
}
```

The Driver Class

```
public class Driver
{
    public static void main(String [] args)
    {
        Person jim = new Person(69,160);
        Person bob = new Person(72,175);
```

```
new
Person(69,160);

new
Person(72,175);
```

The Driver Class (2)

```
System.out.println("Different data, addresses");
System.out.println("Compare data via accessors()");
if (jim.getHeight() == bob.getHeight() &&
    jim.getWeight() == bob.getWeight())
    System.out.println("\tObjects same data");
else
    System.out.println("\tNot equal");

System.out.println("Compare data via equals()");
if (jim.equals(bob) == true)
    System.out.println("\tObjects same data");
else
    System.out.println("\tNot equal");

System.out.println("Compare addresses");
if (jim == bob)
    System.out.println("\tSame address");
else
    System.out.println("\tDifferent addresses");
```

```
Compare data via accessors()
        Not equal
```

```
Compare data via equals()
        Not equal
```

```
Compare addresses
        Different addresses
```

```
Person(72,175); # via set()

Person(72,175);
```

The Driver Class (3)

```
System.out.println();
System.out.println("Same data, different addresses");
jim.setHeight(72);
jim.setWeight(175);
if (jim.equals(bob) == true)
    System.out.println("\tObjects same data");
else
    System.out.println("\tNot equal");

System.out.println("Compare addresses");
if (jim == bob)
    System.out.println("\tSame address");
else
    System.out.println("\tDifferent addresses");
```

```
Same data, different addresses
        Objects same data
```

```
Compare addresses
        Different addresses
```

Person(72,175); # via set()

Person(72,175);

The Driver Class (4)

```
System.out.println();
System.out.println("Same data, different addresses");
jim.setHeight(72);
jim.setWeight(175);
if (jim.equals(bob) == true)
    System.out.println("\tObjects same data");
else
    System.out.println("\tNot equal");
```

```
Same data, different addresses
        Objects same data
```

```
System.out.println("Compare addresses");
if (jim == bob)
    System.out.println("\tSame address");
else
    System.out.println("\tDifferent addresses");
```

```
Compare addresses
        Different addresses
```

jim = bob;

The Driver Class (5)

```
System.out.println();
System.out.println("Same addresses");
jim = bob;
if (jim == bob)
    System.out.println("\tSame address");
else
    System.out.println("\tDifferent addresses");
```

```
Same  addresses
        Same address
```

After This Section You Should Now Know

- References
  - How references and objects are related
  - The difference between a deep vs. shallow copy
  - How to check for if objects are identical (on a field-by-field basis and by implementing an `equals()` method
  - What is the difference between comparing references vs. objects
- How the two methods of parameter passing work, what types are passed using each mechanism
- What are the benefits of employing the indirect mechanism of references-data vs. just data variables
- What is a wrapper class and what is its purpose

James Tam

After This Section You Should Now Know (2)

- How to pass arrays as parameters and return them from methods
- Arrays of 'objects‘
  - Why they are really arrays of references
  - How to declare such an array, create and access elements
- How could a simple simulation be implemented using an array of references
- How to declare class constants
- Static attributes and methods
  - How to create statics
  - How to access statics
  - When something should be static vs. non-static (instance)
  - The difference between static and final

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After This Section You Should Now Know (3)

- Design issues
  - When should something be declared as local vs. an attribute
  - How to determine which attributes and methods should be part of which classes
- What is the 'this' reference
  - When it is and is not an implicit parameter
  - What's the difference between implicit and explicit parameters
  - What are the benefits of having a this parameter

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After This Section You Should Now Know (4)

- Mutable vs. immutable types
  - What is the difference
  - What is the advantage of each type
  - What is automatic garbage collection
- The finalize() method
  - How to define one
  - When is it called
  - What are common uses for this method
  - How is it related to automatic garbage collection
- How to display the current state of an object by implementing a toString() method

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